TESTIMONY OF

DAVID L. EVANS, ASSISTANT ADMINISTRATOR
OFFICE OF OCEANIC AND ATMOSPHERIC RESEARCH
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

BEFORE THE
COMMITTEE ON COMMERCE, SCIENCE AND TRANSPORTATION
UNITED STATES SENATE

July 10, 2001

Good morning, Mr. Chairman and members of the Committee. I am David Evans, Assistant Administrator of the Office of Oceanic and Atmospheric Research. NOAA Research is one of five line offices within the National Oceanic and Atmospheric Administration (NOAA) of the Department of Commerce. I have been invited to discuss the Administration's position on climate change, how the Department is working to improve our understanding of climate, and the Department's programs that may advance technologies which may mitigate climate change.

NOAA is the agency within the Department of Commerce tasked with developing much of the ongoing research on climate change and climate variability and has made major contributions to the understanding of the Earth's climate system. We work in partnership with other federal agencies, scientific organizations, and universities to generate the most accurate and reliable science that we can present on this issue. In recent years, we have worked to identify gaps in our knowledge and capabilities and to determine the impacts that climate change may have on society and the environment. While our role in climate change is non-regulatory, our scientific information is relied upon by policy makers in government and industry, including those in the United States and other countries.

The information I will present to you today is based on a number of findings and mainly represents the state of the science, and the Administration's policies as set forth in the initial report of the Climate Change Review. With respect to the science, I will refer primarily to the set of findings of the 2001 report of the Intergovernmental Panel on Climate Change (IPCC) and the National Academy of Sciences (NAS) June 6, 2001 report, "Climate Change Science: Analysis of Some Key Questions."

For more than a decade, NOAA scientists have been involved in various national and international scientific assessments. These include National Academy of Science studies, World Meteorological Organization/United Nations Environment Programme (WMO/UNEP) reports on the scientific understanding of the ozone layer and IPCC climate change science assessments. In the recently concluded IPCC scientific assessment, four of our scientists served as lead authors, and three of our scientists served as coordinating lead authors on the Technical Summary of the Working Group I Report of the IPCC: *Change 2001: The Scientific Basis*, and the Chapter on *Observed Climate Variability and Change*; the Chapter on *Atmospheric Chemistry and Greenhouse Gases*; the

Chapter on *Aerosols, Their Direct and Indirect Effects*; the Chapter on *Radiative Forcing of Climate Change*; and the Chapter on the *Projections of Future Climate Change*. The Summary was formally approved in detail and accepted along with the underlying assessment report at the IPCC Working Group I Plenary session in January 2001.

The IPCC assessment took almost three years to prepare and represents the work of more than 100 scientific authors worldwide. It is based on the scientific literature, and was carefully scrutinized by hundreds of scientific peers through an extensive peer review process. The independent NAS report was requested by the administration, and was a consensus report compiled by a 11-member panel of leading U.S. climate scientists, including a mix of scientists who have been skeptical about some findings of the IPCC and other assessments on climate change. The NAS panel attempted to better articulate levels of scientific confidence and caveats than the IPCC Summary for Policy Makers.

Before addressing the findings of both reports, two fundamental points are worthy of note. These have been long-known, are very well understood, and have been deeply underscored in all previous reports and other such scientific summaries.

* *The natural "greenhouse" effect is real, and is an essential component of the planet's climate process.* A small percentage (roughly 2%) of the atmosphere is, and long has been, composed of greenhouse gases (water vapor, carbon dioxide, ozone and methane). These effectively prevent part of the heat radiated by the Earth's surface from otherwise escaping to space. The global system responds to this trapped heat with a climate that is warmer, on the average, than it would be otherwise without the presence of these gases.

In addition to the natural greenhouse effect above, there is a change underway in the greenhouse radiation balance, namely:

* *Some greenhouse gases are increasing in the atmosphere because of human activities and increasingly trapping more heat.* Direct atmospheric measurements made over the past 40-plus years have documented the steady growth in the atmospheric abundance of carbon dioxide. In addition to these direct real-time measurements, ice cores have revealed the atmospheric carbon dioxide concentrations of the distant past. Measurements using air bubbles trapped within layers of accumulating snow show that atmospheric carbon dioxide has increased by more than 30% over the Industrial Era (since 1750), compared to the relatively constant abundance that it had over the preceding 750 years of the past millennium. The predominant cause of this increase in carbon dioxide is the combustion of fossil fuels and the burning of forests. Further, methane abundance has doubled over the Industrial Era. Other heat-trapping gases are also increasing as a result of human activities. However, we are unable to state with certainty the rate at which the globe will warm or what effect that will have on society or the environment.

The increase in greenhouse gas concentrations in the atmosphere implies a positive radiative forcing, i.e., a tendency to warm the climate system. Particles (or aerosols) in the atmosphere resulting from human activities can also affect climate. Aerosols vary considerably by region. Some aerosol types act in a sense opposite to the greenhouse gases and cause a negative forcing or cooling of the climate system (e.g., sulfate aerosol), while others act in the same sense and warm the climate (e.g., soot). In contrast to the long-lived nature of carbon dioxide (centuries), aerosols are short-lived and removed from the lower atmosphere relatively quickly (within a few days). Therefore, aerosols exert a long-term forcing on climate only because their emissions continue each year.

In summary, emissions of greenhouse gases and aerosols due to human activities continue to alter the atmosphere in ways that are expected to affect the climate. There are also natural factors which exert a forcing of climate, e.g., changes in the Sun's energy output and short-lived (about 1 to 2 years) aerosols in the stratosphere following episodic and explosive volcanic eruptions. Both reports evaluated the state of the knowledge and assessed the level of scientific understanding of each forcing. The level of understanding and the forcing estimate in the case of the greenhouse gases are greater than for other forcing agents.

What do these changes in the forcing agents mean for changes in the climate system? What climate changes have been observed? How well are the causes of those changes understood? Namely, what are changes due to natural factors, and what are changes due to the greenhouse-gas increases? And, what does this understanding potentially imply about the climate of the future?

These questions bear directly on the scientific points that you have asked me to address today. In doing so, findings emerging from both the recent IPCC and NAS climate change science reports with respect to measurements, analyses of climate change to date, and projections of climate change will be summarized.

** There is a growing set of observations that yields a collective picture of a warming world over the past century.* The global-average surface temperature has increased over the 20th century by 0.4 to 0.8E C [NAS, p.16]. The average temperature increase in the Northern Hemisphere over the 20th century is likely to have been the largest of any century during the past 1,000 years, based on "proxy" data (and their uncertainties) from tree rings, corals, ice cores, and historical records. Other observed changes are consistent with this warming. There has been a widespread retreat of mountain glaciers in non-polar regions. Snow cover and ice extent have decreased. The global-average sea level has risen between 10 to 20 centimeters, which is consistent with a warmer ocean occupying more space because of the thermal expansion of sea water and loss of land ice. The NAS report also found that at least part of the rapid warming of the Northern Hemisphere during the first part of the 20^{th} century was of natural origin.

** There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities.* The 1995 IPCC climate-science assessment report concluded:

"The balance of evidence suggests a discernible human influence on global climate." There is now a longer and more closely scrutinized observed temperature record. Climate models have evolved and improved significantly since the last assessment. Although many of the sources of uncertainty identified in 1995 still remain to some degree, new evidence and improved understanding support the updated conclusion. Namely, recent analyses have compared the surface temperatures measured over the last 140 years to those simulated by mathematical models of the climate system, thereby evaluating the degree to which human influences can be detected. Both natural climate-change agents (solar variation and episodic, explosive volcanic eruptions) and human-related agents (greenhouse gases and fine particles) were included. The natural climate-change agents alone do not explain the warming in the second half of the 20th century.

* *Scenarios of future human activities indicate continued changes in atmospheric composition throughout the 21st century*. The atmospheric abundances of greenhouse gases and aerosols over the next 100 years cannot be predicted with high confidence, since the future emissions of these species will depend on many diverse factors, e.g., world population, economies, technologies, and human choices, which are not uniquely specifiable. Rather, the IPCC assessment aimed at establishing a set of scenarios of greenhouse gas and aerosol abundances, with each based on a picture of what the world plausibly could be over the 21st century. Based on these scenarios and the estimated uncertainties in climate models, the resulting projection for the global average temperature increase by the year 2100 ranges from 1.3 to 5.6 degrees Celsius. Such a projected rate of warming would be much larger than the observed 20th-century changes and would very likely be without precedent during at least the last 10,000 years. The corresponding projected increase in global sea level by the end of this century ranges from 9 to 88 centimeters. Uncertainties in the understanding of some climate processes make it more difficult to project meaningfully the corresponding changes in regional climate. The NAS report agrees with this projection but notes that future climate change will depend on what technological developments may allow reductions of greenhouse gas emissions.

Finally, I would like to relate a basic scientific aspect that has been underscored with very high confidence in all of the IPCC climate-science assessment reports (1990, 1995, and 2001). It is repeated here because it is a key (perhaps "the" key) aspect of a greenhouse-gas-induced climate change:

* *A greenhouse-gas warming could be reversed only very slowly*. This quasi-irreversibility arises because of the slow rate of removal (centuries) from the atmosphere of many of the greenhouse gases and because of the slow response of the oceans to thermal changes (NAS, p. 10). For example, several centuries after carbon dioxide emissions occur, about a quarter of the increase in the atmospheric concentrations caused by these emissions is projected to still be in the atmosphere. Additionally, global average temperature increases and rising sea level are projected to continue for hundreds of years after a stabilization of greenhouse gas concentrations (including a stabilization at today's abundances), owing to the long timescales (centuries) on which the deep ocean adjusts to climate change.

Both reports stress the critical role of the oceans in understanding the Earth's climate system due to the seawater's capacity to store and transport large amounts of heat. While the first study to conclude that the global radiative balance of the Earth system requires heat transport from the tropics to the poles was published almost a century ago, identifying the mechanisms by which heat is transported remains a central problem of climate research. Because of its large specific heat capacity and mass, the world ocean can store large amounts of heat and remove this heat from direct contact with the atmosphere for long periods of time. Studies of ocean subsurface temperature variability were limited due mostly to the lack of data. About 25 years ago, programs were initiated to provide measurements of upper ocean temperature, and for the past 10 years there has been an increase in the amount of historical upper ocean thermal data available. Levitus *et al.* have used these data to prepare yearly, gridded objective analyses for the period of 1960 to 1990. With the use of the World Atlas Database 1998 temperature anomaly fields were prepared. These analyses lead to the quantification of the interannual-to-decadal variability of the heat content (mean temperature) of the world ocean from the surface through 3000-meter depth for the period 1948 to 1998. The mean temperature of the ocean increased by $\sim 2 \times 10^{23}$ joules, representing a volume mean warming of 0.06° C. This corresponds to a warming rate of 0.3 watt per meter squared (per unit area of Earth's surface). Substantial changes in heat content occurred in the 300- to 1000-meter layers of each ocean and in depths greater than 1000 meters in the North Atlantic. The global volume mean temperature increase for the 0- to 300- meter was 0.31° C. Two studies by U.S. scientists *(*Levitus *et al.* and Barnett *et al.)* attempted to address the causes of the world ocean warming using computer model simulations.

These studies were published in the April 13, 2001 issue of the journal of *Science.* Both studies found that the model simulated increase in ocean heat content were comparable to the observed increase only when the effects of greenhouse gases and other forcings were included. The findings further reported that it is unlikely that the observed increases result from random fluctuations of the climate system. The long-term increase requires a sustained warming, such as would be expected from increasing concentrations of atmospheric greenhouse gases. However, this assessment depends upon how well the models simulate the internal variability of the ocean system on time scales of 40 to 50 years.

The NAS study titled "Climate Change Science – An Analysis of Some Key Questions" was released on June 6 and originated from a White House request to inform the Administration's ongoing review of U.S. climate change policy. In particular, the Administration asked for "assistance in identifying the areas in the science of climate change where there are the greatest certainties and uncertainties", and views on "whether there are any substantive differences between the IPCC reports and the IPCC summaries".

The NAS Committee generally agreed with the assessment of human-caused climate change presented in the IPCC Working Group I (WG I) scientific report, but aimed at articulating more clearly the remaining uncertainties. The NAS report summary states: "Greenhouse gases are accumulating in earth's atmosphere as a result of human activities, causing surface air temperatures and subsurface ocean temperatures to rise. Temperatures, are in fact, rising. The changes observed over the last several decades are likely mostly due to human activities, but we cannot rule out that some significant part of these changes are also a reflection of natural variability". Importantly, the report observes: "Because there is considerable uncertainty in current understanding of how the climate system varies naturally and reacts to emissions of greenhouse gases and aerosols, current estimates of the magnitude of future warming should be regarded as tentative and subject to future adjustments (either upward or downward)".

To address this uncertainty, the President has directed the Cabinet-level review of U.S. climate change policy. Based on the Cabinet's initial findings, the President in his June 11 remarks committed his Administration to invest in climate science. He announced the establishment of the U.S. Climate Change Research Initiative to study areas of uncertainty and to identify areas where investments are critical. He directed the "Secretary of Commerce, working with other agencies, to set priorities for additional investments in climate change research, review such investments, and to provide coordination amongst federal agencies. We will fully fund high-priority areas for climate change science over the next five years. We'll also provide resources to build climate observation systems in developing countries and encourage other developed nations to match our American commitment".

I would like to underscore that we will use the descriptions of the uncertainties identified in the NAS report as the basis for development of U.S. research in climate. Cited areas of uncertainty include:

- Feedbacks in the climate system that determine the magnitude and rate of temperature increases
- Future usage of fossil fuels
- How much carbon is sequestered on land and in the ocean
- Details of regional climate change
- Natural variability of climate, and the direct and indirect effects of aerosols

We have convened an interagency working groups to develop a science plan to reduce the areas of uncertainties.

There is a great deal of concern as to what are the CO_2 emissions from various countries, and what scientists are finding about what level of CO_2 reductions are needed to stabilize concentrations in the atmosphere. According to the most recent data from the Carbon Dioxide Information Analysis Center at the Department of Energy's Oak Ridge National Laboratory, countries with the highest CO_2 emissions are: the United States, with 1.49 billion tons of carbon emissions a year; China, with 0.91 billion tons; Russia, with 0.39 billion tons; Japan, with 0.32 billion tons; India, with 0.28 billion tons; Germany, with 0.23 billion tons; the United Kingdom, with 0.14 billion tons; and Canada, with 0.13 billion tons.

Ultimately, due to the long lifetime of CO_2 in the atmosphere to stabilize concentrations we must make progress on net emissions. To achieve this goal, technological advances must be made. Technology will continue to play an important role in reducing greenhouse gas emissions and controlling costs of climate change mitigation. The long-term objective – to stabilize greenhouse concentrations in the atmosphere – can be addressed in two ways: first, by reducing emissions of greenhouse gases; and second, by means of capturing and sequestering gases, either at the source or after they have been released into the atmosphere.

There are significant climate change technology programs at many federal agencies, including notably the Department of Energy, the Environmental Protection Agency, and the Department of Agriculture. I will confine myself to discussion of programs at the Department of Commerce. In the past, the Department of Commerce NIST Advanced Technology Program has funded research into technologies aimed at improving energy efficiency, and increasing the use of low carbon fuels. Similarly, the Manufacturing Extension Partnership helps manufacturers to reduce their dependencies on fossil fuels and use of ozone depleting substances. The NIST Measurements and Standards Laboratory Program also provides the measurement science and data to support climate change studies as well as calibration services relating to atmospheric measurements. These activities contribute to the science base for understanding the behavior of industrial chemicals in the environment, evaluation of environmentally benign chemical alternatives, and measurement techniques for key environmental species in the atmosphere.

In closing, we have outlined a significant number of items that challenge our existing understanding, and we will be placing special emphasis on them in the future. We look forward to continuing to work with you on these issues. Thank you again for the invitation to appear today. I hope that this summary has been useful. I would be happy to address any questions.

<u>Sources of cited information:</u>

Levitus, S., J.I. Antonov, J. Wang, T.L. Delworth, K.W. Dixon, and A.J. Broccoli. Anthropogenic Warming of Earth's Climate System. *Science* 292: 267-270 (2001).

Levitus, S., J.I. Antonov, T.B. Boyer, and C. Stephens. Warming of the World Ocean. *Science* 287: 2225-2229 (2000).

Rossby, C. The Atmosphere and the Sea in Motion. Rockefeller Institute. 1959.

Committee on the Science of Climate Change. Climate Change Science: An Analysis of Some Key Questions. National Academy Press: Washington, D.C. 2001. 28 p.

Summary for Policy Makers, Climate Change 2001: The Scientific Basis. Summary for Policymakers and Technical Summary of the Working Group I Report. Cambridge University Press, 98pp. Also available at http://www.ipcc.ch.
The full report will be available this summer.

Parallel IPCC reports:
Climate Change 2001: Impacts, Adaptation and Vulnerability - Contribution of Working Group II to the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report.

Climate Change 2001: Mitigation - Contribution of Working Group III to the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report.

IPCC, 2000: IPCC Special Report on Emissions Scenarios. Cambridge University Press.